Attachment A: Statement of Work

DETERMINATION OF LATERAL EFFECTS OF BORROW PITS ON HYDROLOGY OF ADJACENT WETLANDS

R. Wayne Skaggs and G.M. Chescheir
Department of Biological and Agricultural Engineering
North Carolina State University

Introduction

The construction of highways requires soil to fill low areas, build overpasses, ramps, and for a variety of other purposes. When the required fill is unavailable from cuts made during the construction process, it is commonly obtained from "borrow pits", usually located close to the highway. In some cases the borrow pits are located in the vicinity of wetlands. This is particularly the case in eastern North Carolina where surface elevations are low and much of the landscape is poorly drained under natural conditions. In such locations it may be nearly impossible to find a site for a borrow pit that is not adjacent to, or in the vicinity of, wetlands. While the North Carolina Department of Transportation's (DOT)specifications for highway construction clearly state that wetlands in the vicinity of borrow areas are to be delineated (http://www.doh.dot.state.nc.us/preconstruct/highway/dsn_srvc/specifications/dual/Division2.pdf) and that a 25 foot buffer between the borrow and adjacent wetlands is to be maintained, there is concern that the borrow pit may serve as a long-term drainage "sink" for the wetland. The concern is that drainage to the pit, after closure, will affect wetland hydrology in a strip of land adjacent to the pit. The purpose of this proposed research project is to develop methods for determining the lateral effects of borrow pits on the hydrology of adjacent wetlands.

Methods were developed in a previous NC DOT sponsored research project (Skaggs, 2000) to estimate the lateral effect of highway drainage ditches on wetland hydrology. The methods are based on solutions to the Boussinesq equation and are described by Skaggs and Chescheir (2002). It seems reasonable to apply these same methods to determine the lateral effects of borrow pits. However there are differences and additional unknowns that must be resolved before the methods developed for highway drainage ditches can be used for determining the lateral impacts of borrow pits. One of the main differences concerns the water level in the borrow pit relative to the water table elevation in the wetland. After the borrow material has been removed and the pit is "closed", the elevation of the water level in the pit will control the hydraulic gradient and determine whether the pit serves as a sink or a source for seepage to or from adjacent wetlands. One of the objectives of this research is to determine the "equilibrium" water level elevation in the pit, and how it varies with weather conditions and season. Once this elevation is known, the methods developed in previous research can be applied to estimate the lateral effect.

The proposed three-year research project has both short-term and long-term objectives. In the short term, methods are needed immediately to estimate lateral effects for current and pending operations. Until better methods are available, we will estimate the "equilibrium" water level in the pit as being one to two feet below the seasonal high water table for the relevant soil series at the pit. This will allow us to calculate the lateral effect using methods previously developed. However, additional work is needed to determine the county specific threshold drawdown times (T_{25} values, see Skaggs and Chescheir, 2002) for the range of depths needed for application to borrow pits. This range is greater than is available from our previous and ongoing work on drainage ditches. Methods will be developed to predict the water level in the pit and how it varies with time. This is considered a long-term objective and will involve both field surveys of pits that have been closed for several years and monitoring of recently closed pits. We expect to develop methods to determine both the "equilibrium" water level and the time required after closure to attain that level. Water balance models will be developed to predict fluctuations of the water level in the pit on a daily and seasonal basis.

Objectives

The overall goal of the proposed project is to develop methods for determining the lateral effects of borrow pits on the hydrology of adjacent wetlands. The methods need to be easy to apply so that, given the same input information, different users would obtain the same result. Specific objectives are listed below.

1. Develop the information necessary to estimate the lateral effect of borrow pits on wetland hydrology using methods developed for drainage ditches.

2. Survey existing (closed) borrow pits that are in close proximity to wetlands to determine characteristics of the pit, soil, and landscape that might affect wetland hydrology.

3. Measure (record) water level rise after closure in 4 to 6 borrow pits in eastern North Carolina and water table elevations in adjacent wetlands.

4. Develop a model to predict the water balance of a borrow pit, the water level rise after closure, the equilibrium water level in the pit, and fluctuations of the water level due to factors such as evapotranspiration (ET), rainfall, and seepage.

5. Conduct workshops to teach DOT personnel, contractors and consultants how to use the methods developed to determine lateral impacts of a borrow pit.

Background

A borrow pit adjacent to a wetland is shown schematically in Figure 1. According to DOT specifications the borrow pit would have to be located at least 25 feet away from the edge of the wetland. However, the lateral effect of drainage to the pit, represented as "x" in Figure 1, may be greater than 25 feet. That is, drainage to the pit might remove wetland hydrology from a strip of land wider than 25 feet. If this is the case a buffer greater than 25 feet would be necessary. In the schematic, we have assumed that the surface of the wetland is at the same elevation as the borrow pit. Because the borrow pit must be located on upland soils, the original ground surface elevation will usually be higher than that of adjacent wetlands. It would rarely be at a lower elevation than the wetland. Thus the schematic may represent a “worst case” scenario with respect to surface elevations.

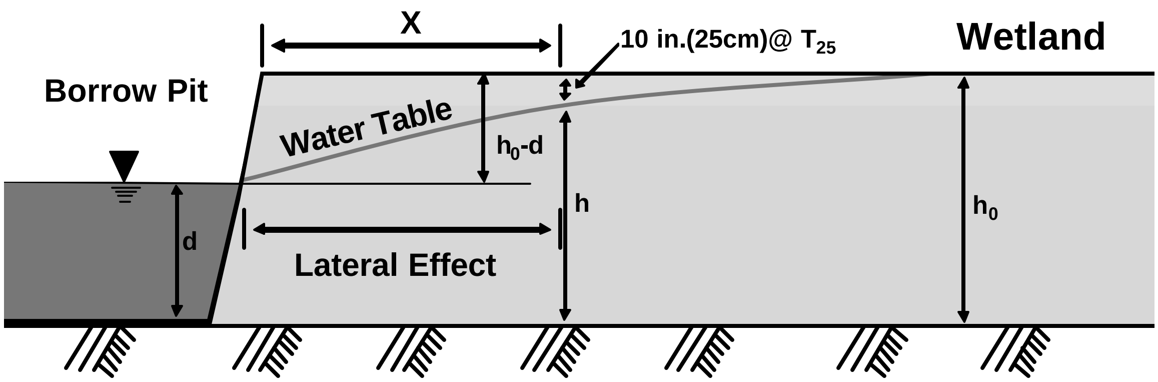

Figure 1. Schematic of seepage from an adjacent wetland to a closed borrow pit.

The water level in the borrow pit will be relatively deep during the time that it is open and soil is being actively mined. In order to keep the pit dry and suitable for mining, ground water is typically pumped from a rim ditch constructed at an elevation somewhat lower than the bottom of the pit. Pit depths in excess of 20 feet are common in eastern North Carolina. Seepage from adjacent or neighboring wetlands to the pit will be at a maximum during this period. However, the effect on wetland hydrology is mitigated by two factors. 1. Water pumped from the pit is nearly always released back into the wetlands; and 2. The pit is only open and actively pumped for a limited period of time. Once mining operations are complete, pumping ceases and the water level in the pit rises to an equilibrium level. This reduces the hydraulic gradient and the effect of the pit on wetlands in the vicinity. The equilibrium water level is defined as the long-term average water level in the pit after it has been closed for some time. It is recognized that the actual water level will rise and fall in response to rainfall, ET, and seepage, but these fluctuations are expected to be small and the water level is expected to remain relatively constant after if rises in the pit following closure. Both the equilibrium water level and the time required after closure for the water in the pit to rise to the equilibrium level are important variables. If the time is relatively short (months), impacts during the active mining phase when the water level in the pit is deep, may be considered temporary and lateral effects can be calculated based on the equilibrium water level. If the time required for the water level to rise to equilibrium is long (years) impacts of deeper water levels in the pit on seepage and the hydrology of adjacent wetlands would have to be considered.

Procedures

Objective 1. **Develop information necessary to estimate the lateral effect on wetland hydrology using methods developed for drainage ditches.**

The methods developed for drainage ditches are described in a paper by Skaggs and Chescheir (2002). A copy of the paper is attached (Appendix B). Research was conducted using DRAINMOD (Skaggs, 1978, 1999) to determine drainage conditions that define wetland hydrology. Simulation analyses were conducted on five hydric soils covering a wide range of hydraulic conductivities and profile transmissivities. Results indicated that minimum conditions for wetland hydrology could be defined in terms of a threshold water table drawdown rate. For example, wetland hydrology will exist for sites near Wilmington, NC if drainage rates are such that it takes more than 6.3 days to lower the water table (by drainage alone) from the surface to a depth of 25 cm (10 in.). That is the threshold drainage rates are defined in terms of the time required to lower the water table by 25 cm (10 inches). This threshold time is referred to as T_{25}, and was found to be independent of soil type, but dependent on drain depth, location, and surface depressional storage in the wetland.

Work on this objective will mostly involve determining T_{25} values for relevant counties and for a range of depths between the equilibrium water level in the pit and the wetland surface. These values will supplement values obtained in the project to determine the effects of highway drainage ditches (Skaggs, 2000, 2004). In order to provide the inputs necessary to calculate lateral effects of borrow pits on pending projects, we will determine these coefficients in the early part of the project. Values for 6 counties are given in Table 1. Values will be determined for additional counties in priority order according to needs identified by DOT and communicated to the principal

Table 1. Summary of T_{25} values (in days) for six North Carolina Coastal Plain counties for surface depressional storage of 1 inch (2.5 cm).

Depth of water in pit below surface	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft
Craven	5.14	5.21	6.02	6.87	7.50	8.14
Cumberland	6.30	6.29	7.40	8.56	9.10	9.67
New Hanover	4.51	5.45	5.85	6.28	6.65	6.88
Pasquotank	6.02	6.55	6.70	7.36	8.10	8.80
Washington	9.07	7.85	8.12	8.87	9.59	10.2
Wilson	11.0	11.2	11.4	12.0	12.0	12.8

investigator. We anticipate completing this work during the first year of the project, with the counties highest on the priority list being done first and reported to DOT as they are completed.

We will also determine whether this method, or a modification of it, can be used to determine effects of the borrow pit on seepage from adjacent streams.

Objective 2. Survey existing (closed) borrow pits that are in close proximity to wetlands to determine characteristics of the pit, soil, and landscape that might affect wetland hydrology.

A survey will be conducted on 50 to 75 closed borrow pits that are located close or directly adjacent to wetlands. We will seek the assistance of DOT personnel (Roadside Environmental) in identifying potential sites and supplying relevant available data. Each site will be visited to determine the following data.

a. Distance from wetland
b. Topography with respect to wetland
c. Depth of water in pit
d. Time required for water to equilibrate (estimated based on observations by local observers)
e. Factors affecting water level (depth from ground surface) in pit (presence of adjacent or intercepting ditches, use of water for irrigation or other, etc.)
f. Hydraulic gradient with respect to wetlands
g. Soil series at the pit and in the wetlands
h. Other factors that might affect water levels in the pit and the hydrology of the wetlands

Results of this survey should give us a good indication about equilibrium water levels in the pits and how it compares with seasonal high water tables, and with surface elevations of adjacent wetlands. It will also be valuable to determine the direction and magnitude of the hydraulic gradient. Is the gradient actually from the wetland to the pit as we have assumed, or in the other direction some of the time? Statistics on the findings of the survey will be compiled and reported.

Objective 3. Measure (record) water level rise after closure in 4 to 6 borrow pits in eastern North Carolina and water table elevations in adjacent wetlands.

Four to six active borrow pits will be selected for monitoring. We will request the assistance of DOT to identify active mining sites that are nearing closure, have adjacent wetlands, and are geographically distributed in eastern NC where the problem typically exists. At the time of closure (when pumping of groundwater form the pit is terminated) we will install water level recorders in the pit and in at least one transect (3 to 5 wells) leading from the pit to adjacent wetlands. Both a recording and a manual rain gauge will also be installed on the site. Our research engineer or technician will visit the site at 2-week intervals to download data and service the equipment. The data will be immediately processed and archived for future analysis. These measurements will give us important data on both the equilibrium water level and the time required for water in the pit to rise to that level. They will also document hydraulic gradients from the wetland to the pit and their evolution following pit closure. By recording the water levels for a 2 to 3 year period, we will also be able to observe the water level fluctuations in the pit on a day-to-day and seasonal basis. These data will be used to test water balance models we will develop to predict water levels in the pit and their changes with time. It is recognized that the rate of water level rise in the pit is weather related. So, to the extent possible, we will select pits that will be closed at different times of the year to measure responses under different weather conditions.

Objective 4. Develop a model to predict the water balance of a borrow pit, the water level rise after closure, the equilibrium water level in the pit, and fluctuations of the water level due to factors such as evapotranspiration (ET), rainfall, and seepage.

One of the problems in evaluating the time required for the water level in a closed borrow pit to rise to an equilibrium elevation is the effect of weather on the process, and its temporal variability, both seasonally and from year-to-year. Obviously the time required for the water level to rise would be short if closure occurs just before hurricanes or tropical storms dump large amounts of rainfall on the site. In order to assess the time required for the water table to rise in a pit following closure, a water balance model for the pit will be developed. The model will consider rainfall, ET, and seepage to and from the pit. DRAINMOD based models are available to predict, on a day-to-day basis, the water table depth in the lands surrounding the pit, including wetlands. The water balance model will use outputs from these models for surrounding lands to predict seepage into and out of the pit. This will enable us to predict on a continuous basis the water level in the pit, including the period when it rises immediately after cessation of pumping when the pit is closed. It could also be used to predict the effect of pumping water from the pit for irrigation or other purposes, and the consequent effect on seepage to or from wetlands. The validity of the model will be tested by comparing it with measurements described in procedures for objective 3 above.

Once the water balance model has been developed it will be applied to predict the time required for the water level rise to equilibrium conditions in the pit. We will use a long-term weather record to determine the time required for various weather conditions. This will be done by simulating pit closure at different times distributed along the continuum of months and years of data in the weather record. For example, we could simulate the water level response after pit closure on May 1, 1970. The model would predict the pit water level on a daily basis for the next 30 years. By examining predictions for the first several months of the predictions, it would be a simple matter to determine the time required for the water level to rise to an equilibrium condition. The "equilibrium" condition would also be defined by the predictions (as it will in our monitoring in objective 3). That is, our measurements and predictions will indicate whether the equilibrium depth of water below surface is, for example, 4 ft +/- 0.5 ft, or 4 ft. +/- 2.0 ft. Then we would repeat the simulations starting at another date, say September 1, 1970, to see how the time required for the water level to equilibrate varies with weather conditions following closure on this date. This procedure will be repeated many times, starting at different dates. Statistics will be developed on the average and range of times required for the pit water level to rise to equilibrium. In this way we can avoid bias in our conclusions regarding time required for the water table to rise. The measurements described in objective 3 will define precisely the time required for the water level to rise in the pits we monitor. But these results will depend on weather conditions during the time we make the measurements. They may not be representative if they are made during periods of very heavy rainfall or during a prolonged drought. The model will allow us to examine the response for the wide range of weather conditions that occur in the region.

Objective 5. Conduct workshops to teach DOT personnel, contractors and consultants how to use the methods developed to determine lateral impacts of a borrow pit.

A number of workshops will be conducted during the course of this project. The first workshop will be conducted in the late summer or fall of this year (2004) to teach DOT personnel, consultants and contractors how to apply, to borrow pits, the methods developed for determining lateral effects of ditches on wetland hydrology. We will determine the T_{25} values for the counties of highest priority (those where new pits will be opened soon for projects in process or to be initiated in the next few months) early in the project and will have them available for use in the workshop. Separate workshops can be scheduled for DOT engineers, contractors and consultants if desirable. Additional workshops will be scheduled as the work progresses, at least on an annual basis. We will update methods as warranted by results of our research. For example, our interim procedure will be to assume that the equilibrium water level in the pit is 1 to 2 feet below the seasonal high water table. Results of our field survey (Objective 2) may indicate that the water level is either closer to the surface or deeper than this estimate. Such updates will be incorporated in the procedures as we go along. We will report progress on the project quarterly and work with DOT personnel to schedule workshops as needed. In addition to workshops, it will be important to keep the US Army Corps of Engineers (COE) informed of progress on the project. The P.I. will be available (at the request of DOT) to present our findings to the COE on an annual basis and to meet with them more frequently as necessary to address special problems or issues related to the application of this research.

Expected Products of the Proposed Research:

1. A simplified method for determining the lateral effect of borrow pits on the hydrology of adjacent wetlands.

2. Results of a survey on the characteristics of borrow pits that are adjacent to or in the vicinity of wetlands, including the equilibrium water level in the pits and the hydraulic gradient toward the wetland.

3. Experimental determinations of the water level response in borrow pits after closure for 4 to 6 sites.

4. A model for predicting the water level in the borrow pit after closure, the time required to reach equilibrium conditions and day to day fluctuations of the water level in response to rainfall, ET, and seepage.

5. An experimental evaluation of the zone of influence of borrow pits on adjacent wetlands for four to six sites.

6. Workshops for training DOT personnel on the application of the methods and interpretation of the results. Workshops will be scheduled starting in year 1 of the work. Multiple

workshops will be conducted to train all DOT engineers, consultants and contractors interested in applying the methods.

7. A report describing the research and its results. A users manual for the application of the results would be part of the final report.

8. Results of the work will be published in refereed journal articles.

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